6

Recommendations for Meeting the Grand Challenge

The preceding sections of this report make a compelling argument that while much has been accomplished there is still much to be done to prevent earthquake disasters in the United States. Limiting or reversing the growth of seismic vulnerability in the United States will require a vigorous earthquake engineering research program over the next 10 years and beyond. Although earthquake engineering research has led to major advances over the past 30 years, much of this research is along fairly narrow, discipline-specific lines and is not well integrated from a broad systems perspective. Although the traditional research model has produced much work of value and undisputed improvement in the performance of the built environment, such fragmented research activities are not able to keep pace with the accelerating demands for new, more complex hazard mitigation solutions.

The committee believes that NEES, as the collaboratory network for earthquake engineering simulation, can make major contributions to developing comprehensive and fully integrated earthquake simulations that connect credible expectations for seismology and geophysics at one end with private and government actions to reduce risk at the other. Results from these simulations will need to couple with building inventories, historical earthquake damage, and alternative build-out scenarios and will drive performance-based system designs, pre-event mitigation planning, emergency response, and post-event assessment and recovery. Knowing the magnitude and likelihood of expected losses would provide a benchmark for the value of mitigating actions, from better site selection, to improved structural designs, to land use regulation. Ultimately, knowledge-based systems will be developed to support decision-making by policy makers and planners.

This is why the NEES collaboratory is so timely: By promoting collaboration and the sharing of resources, NEES can accelerate the pace of earthquake engineering research and the deployment of solutions to complex problems in earthquake hazard reduction. The NEESgrid will be a comprehensive system for archiving and sharing research data, real-time streaming of video, experimental and simulation processes, teleparticipation in experimentation at distant locations, and other features yet to be conceived.

Although most NEES research will focus on expanding the science and technology knowledge base, public policy actions that translate research results into practice are essential for ultimately preventing earthquake disasters. These actions include land use planning and zoning, building code adoption, enacting requirements for identifying and correcting hazards in existing buildings and lifelines, and either directly funding or providing financial incentives for risk reduction. Informed decisions by property owners, businesses, and public utilities—such as whether to retrofit existing facilities, invest in new facilities, or sell vulnerable facilities and relocate to safer sites—also are essential for preventing earthquake disasters.

Similarly, it is crucial to increase capabilities for preearthquake preparedness and emergency response, including more advanced simulation, instrumentation, and communication capabilities. Finally, education and the dissemination of policy information are key to developing effective approaches to creating public awareness and achieving policy objectives, and the

research community should provide the necessary simulations, demonstrations, and curricular materials for this effort.

All of these efforts will require multidisciplinary collaboration between the scientists and engineers who will develop and test new theories on earthquakes, earthquake damage, and its mitigation, and the social and political scientists who will use the science and technology that will come from NEES to develop better risk assessment tools, loss estimation models, and communication and teaching strategies to help enact and implement more enlightened policies on earthquake loss mitigation.

The remainder of this chapter presents the committee's recommendations. They are offered in the spirit of helping NSF and the NEES Consortium realize the full potential of this ambitious and worthwhile initiative and to make NEES truly a new paradigm for earthquake engineering research.

RECOMMENDATIONS

Recommendation 1. The National Science Foundation should encourage and fund at appropriate levels research projects that address the high-priority issues in earthquake engineering and science identified by this committee. Special emphasis should be placed on grand challenge research activities that include multiple equipment sites and investigators from many disciplines.

Complex, multidisciplinary, grand challenge research problems were identified and presented in Chapter 3 of this report. In Chapter 5, the committee articulates a research agenda with short-, medium-, and long-term goals that it believes should be pursued under the NEES initiative. The committee believes that NEES can address and resolve the problems that underlie progress in earthquake engineering by engaging several of the new equipment sites and investigators from many disciplines who may be located at the NEES equipment sites or elsewhere. Understanding can thus be advanced in quantum leaps rather than small, incremental steps. Several examples of collaborative partnerships are described in Chapter 3. Funding levels are discussed in Recommendation 3.

Recommendation 2. NSF should also support NEES projects of more modest scope that will produce and report useful results within a 2 to 3 year timeframe. These projects could serve as models for additional studies and demonstrate positive outcomes that would encourage other investigators to become involved in NEES collaborative research.

NEES is an ambitious program that has the potential to revolutionize the way that earthquake engineering research is conducted. Revolutions such as this do not happen overnight, however, and the adoption and acceptance of new technologies by a broad community are a matter having sociotechnical dimensions. NEES will have to demonstrate solid progress on tangible goals that are desirable and beneficial to researchers, practitioners, and educators alike, as well as to society in general. Compelling examples of what is possible are needed in order to accelerate interest, acceptance, and the critical community feedback processes that will inform the continued evolution of NEES.

Recommendation 3. The National Science Foundation should ensure that funding is provided for appropriate maintenance, support, and utilization of the NEES investment. At the same time, funding to support and maintain the research infrastructure not located at NEES equipment sites should be continued at an appropriate level.

First, the committee notes that the various NEES equipment sites will serve as the core of NEES research activities. In addition to the testing equipment, this extensive research infrastructure will include many educators, researchers, graduate students, and technicians. Fully developing the capabilities of NEES will require that at each equipment site, the various players function as a team and learn to work together to produce the best results possible. To do this will require that the equipment and the research team be continuously engaged in testing and experimentation—and that the team has adequate resources to do so. It is the committee's carefully considered opinion that high-quality research can be produced consistently only if the equipment is fully utilized, so that the research staff can learn its capabilities and limitations and maximize their skills. The committee believes that adequate funding must be available to operate and maintain the equipment sites in a high state of readiness.

Second, NEESgrid is more than just a systems integration project. It encompasses the codevelopment of new collaboration technologies and data standards and is being constructed on information technologies that are new and evolving rapidly. There may be some expectation that the foundational information technologies are fixed investments somewhat like the NEES equipment but they are not the same. Once the initial system integration project (i.e., NEESgrid) is complete (in 2004), a substantial foundation will be in place, but many problem-specific applications and capabilities will still need to be developed. Dedicated funding will be required to continue developing the IT components of NEES and to realize the research goals.

The committee is aware that there will never be enough money to fund everything that's important and regardless of how much funding is provided, there will always be more needs than resources to address them. For this reason, an effort was made to develop a convergent solution. The committee identified the research needs and then, based on its collective experience, determined the basic amount necessary to operate and maintain a research program using the NEES infrastructure investment. The collective experience of the committee members suggests that the annual operating costs of large engineering research machines are on the order of fifty per cent of the capital cost. In the case of NEES, this would be somewhat more than $40 million. The committee did not try to determine the level of investment in NEES research that was justified by the expected benefits; the long term payoff is so great as to justify almost any investment level. The EERI research plan recommends funding in the amount of $325 million for fiscal years (FY) FY2004 through FY2008. This amount is for the entire earthquake program and includes earthquake prediction, engineering research, technology transfer, and education. Approximately $240 million, or an additional $48 million per year for the next 5 years, would be applicable to research that could be conducted through NEES and the committee selected this as a baseline amount. This amount is of the same magnitude as the committee's empirical estimate, and on this basis, the committee believes that NSF should be prepared to provide this general level of funding ($40 to $50 million per year) as a minimum to support the NEES initiative. In light of this, the committee strongly recommends that NSF initiate whatever actions are necessary to ensure that this level of additional funding is available so that NEES can meet the grand challenge of ultimately preventing earthquake disasters. Should more funding be made

available, the pace of research could be accelerated and the benefits of that research realized sooner.

Recommendation 4. The National Science Foundation, as the lead agency in the NEES partnership, should assume leadership and put in place a management structure to articulate objectives, identify and prioritize research needs, and assure a stable flow of support to achieve the objectives established for NEES. This should include the establishment of an advisory body to provide strategic guidance to NEES program activities.

To fulfill its potential and articulate and implement the vision of ultimately preventing earthquake disasters, NEES will require focused leadership. Research results must be tied to clearly understood objectives for earthquake loss reduction that transcend findings in a single discipline or group of disciplines. Achieving these objectives will require proactive management of the program that reflects problem-oriented, interdisciplinary research. The committee believes that unlike traditional NSF research initiatives, strategic guidance must be provided from within NSF itself. It is for this reason that the committee recommends the establishment of a strategic advisory group to engage the entire community of interest for earthquake engineering research. The mission of this group would be to assess, periodically, progress in resolving critical issues and to outline promising areas for NEES to pursue as research results become available. The periodic assessments would provide a framework for identifying and prioritizing research directions, and for allocating funding levels among program activities, and it would also establish performance objectives for new lines of inquiry. The advisory body could also work with NSF and the NEES Consortium to identify opportunities for the implementation of NEES results. It should include a broad range of disciplines to include the earth, social, and policy sciences, engineering, and computational modeling and be geographically representative as well.

Recommendation 5. The National Science Foundation and other stakeholder agencies should develop a partnership with a shared vision for earthquake loss reduction and for undertaking research and development to achieve that vision.

In addition to NSF, the NEES Consortium, the agencies of the National Earthquake Hazards Reduction Program, federal, state, and local government agencies, government laboratories, and private industry all have some responsibility for addressing earthquake hazards. Effective outreach and coordination with these groups will maximize the effectiveness of NEES in creating earthquake-resistant communities.

Recommendation 6. The partnership of public and private organizations that will support NEES efforts should build a national consensus to ensure that the research and development needed to achieve earthquake loss reduction is fully appreciated at all levels of government and is provided with adequate resources to realize the vision of ultimately preventing earthquake disasters in the United States.

The NEES community must extend far beyond the designated NEES equipment sites and must foster the democratization of earthquake engineering research. NEES participants should include personnel at universities of all sizes, government laboratories, government agencies involved with the National Earthquake Hazards Reduction Program, private industry, and public

policy makers. Ongoing financial support through NSF will be required to fund individual and multicollaborator research and to keep pace with the rapidly evolving landscape of information technology. Private industry should consider NEES as a resource for the development of solutions, and collaboration between NEES and private industry should be promoted to create a direct conduit between research and practice. The agencies of the National Earthquake Hazards Reduction Program, as well as other agencies at all levels of government, will benefit significantly from interactions with NEES. Government agencies should consider NEES as an adjunct in fulfilling their program needs and therefore should consider providing both logistical and financial support to NEES. As NEESgrid evolves, NSF and NEES will need to develop information management policies that recognize the intellectual property interests of individual participants while serving the needs of the larger research community by allowing it to access all NEES-generated research data. The data-related efforts of the NEES project are fundamental to its success and are being well received by researchers and practicing engineers alike. Progress in advancing data and metadata efforts for the earthquake engineering community is only in its infancy, but advances in this area are likely to have a high return on investment. These activities will have to be prioritized, funded, and continued into the future.

Recommendation 7. In addition to the potential of NEES to foster collaboration in research, its capabilities as a tool for education and outreach should be exploited to the greatest extent possible.

The ultimate success of NEES will be demonstrated by its ability to impact society and reduce earthquake risk. The results of NEES research must be transferred to individuals and institutions that can take advantage of them and implement the knowledge gained. Earthquakes, tsunamis, and natural disasters are enormously relevant and interesting to society in general and to students in the classroom. Web-based environments for posing questions, running simple, idealized model experiments or simulations or even engaging in simulated disaster response management offer exciting possibilities for leveraging NEES capabilities. NEES has a responsibility to contribute to the education of students, the continuing education of faculty, and the elevation of public awareness about earthquake engineering and earthquake hazard in society as a whole. To maximize the impact of NEES research results, the NEES Consortium should generate public policy briefs, press releases, and educational resources for the general public. For standards writers and practitioners, research results should be conveyed in a format that presents the relevant technical findings of the research and their impacts on practice. The NEES Consortium should facilitate open discussion between standards writers, practitioners, and researchers in order to clarify the implications of the research and identify gaps in understanding for future research endeavors.

Recommendation 8. Although NEES is directly targeted at earthquake engineering research, its capabilities for simulation, physical testing, and experimentation can and should be applied to a wide range of civil engineering applications.

The physical modeling, numerical simulation, and networking tools developed through NEES can be utilized to study and solve problems in an entire spectrum of geotechnical and structural engineering applications, such as the effect of construction and traffic vibrations on structures, the preservation and repair of historic structures, the impact forces of large debris

such as cars and trees transported by floods, and the effect of intense heat and explosions on structural performance. Researchers interested in studying these and other appropriate issues should be invited to use NEES facilities when they are not fully occupied with earthquake engineering research. In addition, the Department of Homeland Security, government laboratories, and other federal agencies should be encouraged to treat the NEES collaboratory as a resource for enriching their own programs and should consider both logistical and financial support for NEES.

Recommendation 9. The capabilities of NEES should be viewed as a global asset whose value can be utilized for increasing the U.S. contribution to international earthquake loss reduction.

Although NEES is a national effort, earthquake research is a global concern, and NEES must play a long-term role in advocacy, partnerships, and joint research with other national and international projects. While knowledge transfer between developed nations has already accelerated the development of sophisticated earthquake-resistant design, NEES can do more with the dissemination of technology and knowledge transfer to developing nations. Proactive investments made with respect to the identification of problems in, and technology transfer to, developing countries will reduce future expenditures on earthquake-related disaster relief, limit the enormous detrimental effects of earthquake disasters on already struggling economies that are often felt worldwide, and satisfy a moral imperative to reduce the number of lives lost in future seismic events.

Recommendation 10. Although the potential value of research conducted under the aegis of NEES is enormous, it is important that individual researchers and other groups not directly affiliated with NEES equipment sites be supported.

The strength of the NEES vision is in collaborative and integrative research that combines theory, experimentation, computational modeling, and physical testing for model validation. Integrating across disciplines will help to foster the problem-oriented research that is required to translate research results into effective risk-reduction practice. The need for multidisciplinary efforts suggests that multi-investigator and multi-institutional research will play an important role. At the same time, NSF needs to ensure that innovative, single-investigator research continues to thrive. There is a grave concern among many researchers in the earthquake engineering community that the NEES program will jeopardize the funding of researchers not directly affiliated with NEES equipment sites or with large, established engineering research organizations such as the national earthquake engineering centers. Similarly, there is concern among researchers not affiliated with NEES equipment sites or earthquake centers that the concentration of resources in those locations will place them at a competitive disadvantage for funding and attracting top-flight graduate students. NSF must ensure that researchers not directly affiliated with NEES equipment sites continue to receive strong support and that the NEES program is inclusive, drawing on a broad and diverse set of researchers. Efforts will have to be made to foster the formation of diverse teams in pursuit of solutions to the grand challenges in earthquake engineering. Funding initiatives that combine, for example, collaborative efforts among NEES awardees, the national earthquake engineering centers, and university researchers not located at equipment sites, researchers at government

laboratories, practicing engineers, social and policy scientists, and information technologists will be required in order to accomplish this. An important potential role for the NEES Consortium will be to promote the development of new, cross-disciplinary research proposals that span these cutting-edge areas, establishing partnerships between NEES experimental researchers and numerical modelers, practicing engineers, and academic researchers in computer and computational science and engineering, information technology, and knowledge systems.